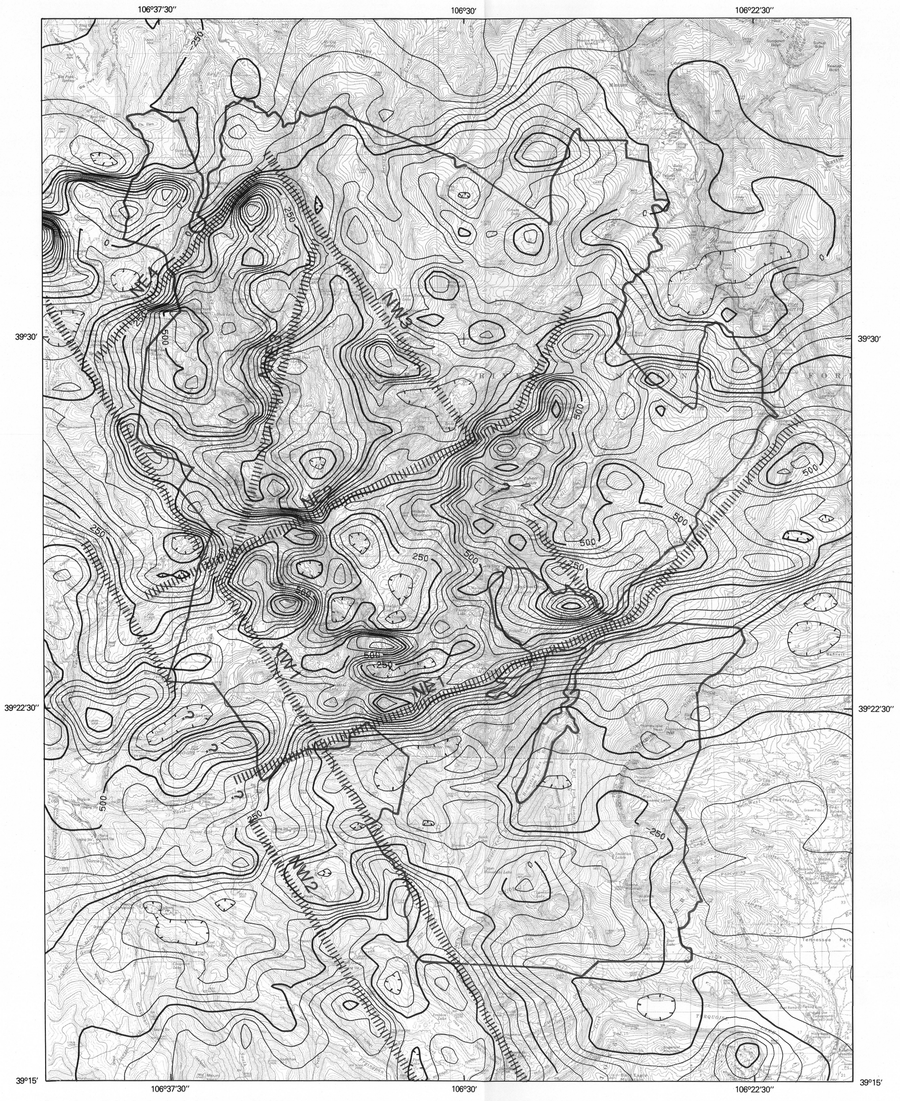


Base from U.S. Geological Survey, 1:50,000
County Map Series, Eagle, Lake, Pitkin, 1975

SCALE 1:100 000

CONTOUR INTERVAL 100 FEET
NATIONAL GEODETIC VERTICAL DATUM OF 1929

MAP A. AEROMAGNETIC MAP

EXPLANATION OF MAP A

Boundary of Holy Cross Wilderness

Magnetic contours--Contour interval, 50 nT; hachures indicate closed lows

Magnetic lineament

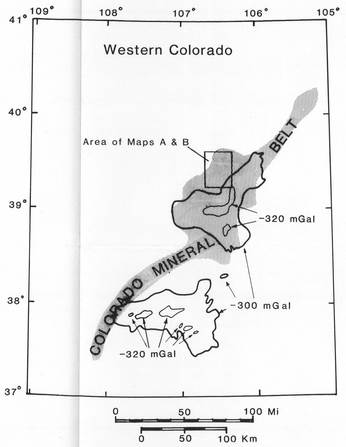


Figure 1.--Map of western Colorado showing correlation between complete Bouguer gravity anomaly low, indicated by -300 and -320 mGal contours, from Behrendt and Bajwa (1974), and Colorado mineral belt (shaded), from Tweto and Sims (1963).

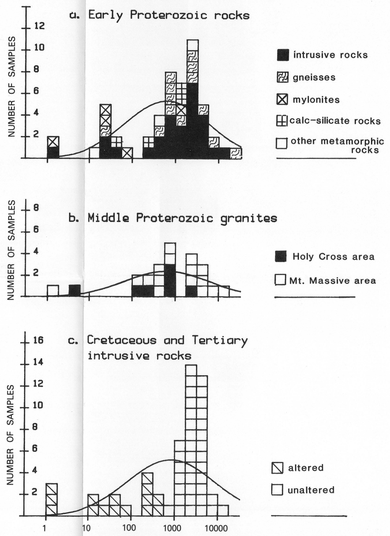
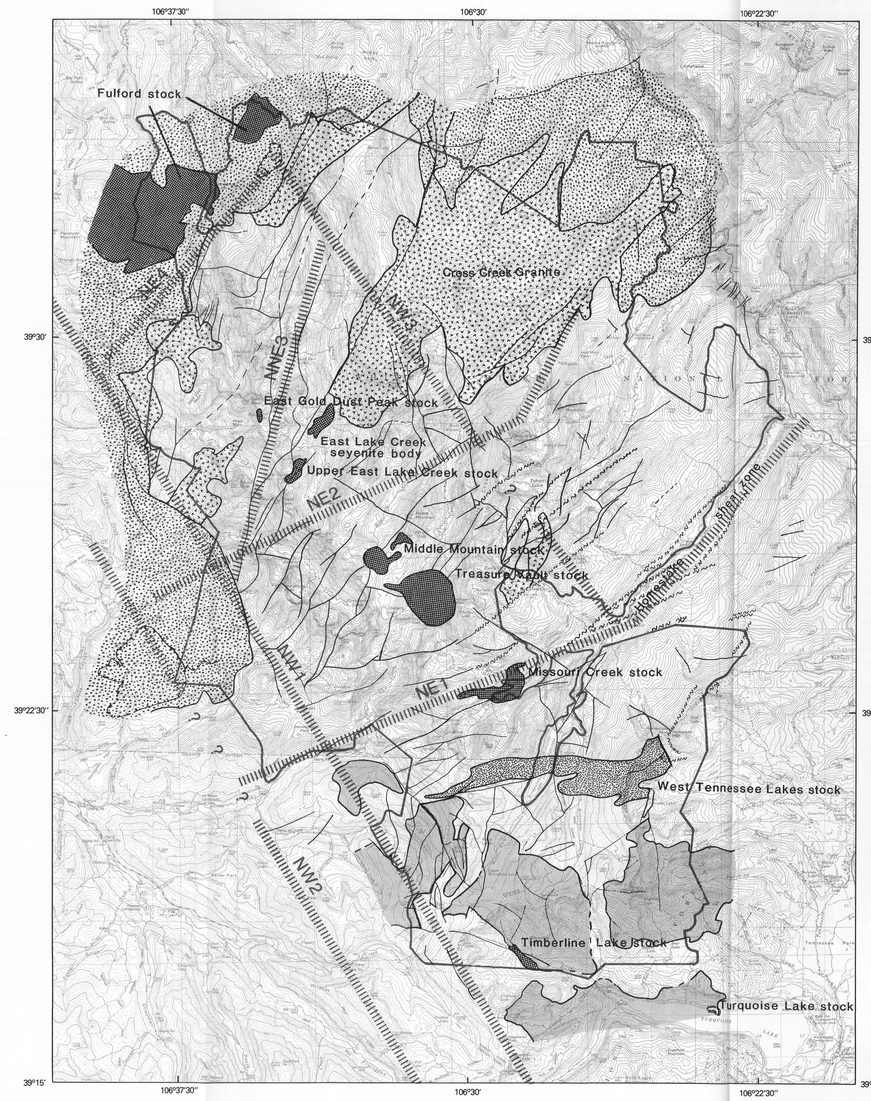


Figure 2.--Lognormal histograms of magnetic susceptibilities measured from samples collected in and near the Holy Cross Wilderness. A normal curve (solid line) has been fit to the histograms. Samples marked "altered" show quartz-sericite-pyrite alteration.



Base from U.S. Geological Survey, 1:50,000
County Map Series, Eagle, Lake, Pitkin, 1975

Geology simplified from Wallace and others (1986)

SCALE 1:100 000

CONTOUR INTERVAL 100 FEET
NATIONAL GEODETIC VERTICAL DATUM OF 1929

MAP B. GENERALIZED BEDROCK GEOLOGY

EXPLANATION OF MAP B

Cretaceous or Tertiary intrusive rocks

Paleozoic rocks

Middle Proterozoic intrusive rocks, including St. Kevin Granite

Early Proterozoic intrusive rocks, including Cross Creek Granite

Early Proterozoic calc-silicate rocks

Early Proterozoic metamorphic rocks

Boundary of Holy Cross Wilderness

Magnetic lineament

Fault--Dashed where approximately located

Shear zone

INTRODUCTION

The Holy Cross Wilderness (02-170), called simply "the wilderness area" in this report, lies in the northern Sawatch Range of Colorado. Regionally, the wilderness area lies on a strong gravity gradient that marks the northwest side of the deepest gravity low in the central United States (Behrendt and Bajwa, 1974). This low (fig. 1) reflects a series of Laramide and younger granitic intrusive bodies which are probably related genetically to the Colorado mineral belt (Tweto and Sims, 1963; Behrendt and others, 1968).

The wilderness area lies on a structural dome, on which Proterozoic basement rocks have been uplifted, exhumed, and sculpted by glacial and fluvial erosional processes into spectacular alpine ridges. Steep faults bound the western edge of the dome; west of these domal border faults lies a sequence of Paleozoic sedimentary strata, which dip gently and thicken to the west. The dome is marked by an oval regional gravity high (Webring, written commun., 1985) whose shape suggests that maximum domal uplift may have occurred along or just to the east of the domal border fault complex. For more extensive descriptions of the regional geologic setting and mineral deposits of central Colorado, see Tweto (1968).

Map B is a generalized bedrock geologic map of the wilderness area, showing locations of faults, shear zones, and geologic units referred to in this report. Many smaller outcrops are not shown on Map B, however. For precise locations, descriptions of geologic units, and a more complete discussion of the geology of the wilderness area, see the companion map by Wallace and others (1986).

MAGNETIC SUSCEPTIBILITY MEASUREMENTS

Figure 2 shows histograms of magnetic susceptibilities of 111 rock specimens from the wilderness area. The samples chosen were thought to be typical examples of the major rock types there. Susceptibilities were measured using a Geoinstrument JH-8 meter.[1] The JH-8 meter has a measurement threshold of approximately $2x10^{-5}$ S.I. units; all rocks with susceptibilities below that threshold are shown as $1x10^{-5}$ S.I. unit.

The samples were grouped into three classes based on age: Early Proterozoic metamorphic and intrusive rocks, Middle Proterozoic granites or granitoid rocks, and Cretaceous and Tertiary intrusive rocks. To make part b of figure 2, values for 16 samples of Middle Proterozoic granitoid rocks from nearby parts of the Mount Massive Wilderness area were used together with the six measured samples from inside the Holy Cross Wilderness proper. Figure 2 shows that the susceptibilities of rocks in all three classes vary widely. Normal curves were fit to the histograms, and antilogs of their maxima took the following values: $600x10^{-5}$ S.I. for Early Proterozoic rocks ($425x10^{-5}$ S.I. for the Early Proterozoic metamorphic rocks if taken separately; $860x10^{-5}$ S.I. for the Early Proterozoic intrusive rocks if taken separately), $620x10^{-5}$ S.I. for Middle Proterozoic granitoid rocks, and $740x10^{-5}$ S.I. for Cretaceous and Tertiary intrusive rocks. The standard deviations of all the above populations substantially overlap, and there is no statistically significant difference between the susceptibilities of the rock classes. We conclude that rocks of different ages cannot be distinguished using their present-day susceptibilities.

Among the rocks that make up the above general classes were several textural and petrological variations that were mapped or capable of being mapped. Measured susceptibilities appeared to us to reflect several such variations, though not enough samples were measured to verify our impressions statistically. Early Proterozoic intrusive samples from the Cross Creek Granite, for example, typically had higher susceptibilities than those from other parts of the wilderness area. Of the Tertiary and Cretaceous intrusive rock group, those from Fulford-type stocks had relatively higher measured susceptibilites than samples from the other stocks. (Fulford-type stocks comprise the Fulford stock, Gold Dust Peak stock, upper East Lake Creek stock, Missouri Creek stock, and West Tennessee Lakes stock.) Altered samples from all classes had generally lower susceptibilities. Rocks with mylonitic textures (that is, those from shear zones) also tended to have lower susceptibilities.

AEROMAGNETIC MAP

An aeromagnetic survey of the wilderness area was flown in the summer of 1984 by the U.S. Geological Survey (Godson and others, 1985). The survey was flown along east-west lines spaced approximately one mile apart. Where possible, the pilot draped the flight 1,000 ft above the ground, but in many places had to fly higher to clear the rugged topography. The survey data were corrected for tides and diurnal changes and reduced to the 1980 International Geomagnetic Reference Field updated to 1984 (Fabiano and others, 1983) by U.S. Geological Survey personnel. Map A shows the resulting contour map of the residual aeromagnetic field. Map A generally shows a U-shaped magnetic high that is centered over the dome and opens to the northeast. A grid of "magnetic lineaments" seems to be present, one set trending north-northwest and the second set trending northeast (striped lines on maps A and B). A magnetic lineament is a set of aligned segments consisting of several parallel contours that persist over a substantial distance. We chose the magnetic lineaments shown on maps A and B subjectively, by eye. The northeast-trending magnetic lineaments are thought to reflect Proterozoic geologic features, whereas the north-northwest-trending magnetic lineaments are thought to reflect mainly Laramide and younger geologic features.

A major north-northwest-trending magnetic lineament ("NW1" on maps A and B), herein termed the "Mount Massive-Fulford lineament," extends from near Mount Massive, south of the study area, north-northwest to the headwaters of Last Chance Creek and on in a straight line to near Fulford. The southern (Mount Massive to Last Chance Creek) part of this lineament has the more magnetic rocks on the southwest, whereas the northern (Last Chance Creek to Fulford) segment has them on the northeast. In the Mount Massive area, the relatively magnetic source rocks have been tentatively identified as a coarse-grained, porphyritic phase of Middle Proterozoic granites which occur there (Van Loenen, written commun., 1985). The northern part of the lineament corresponds to a major domal border fault. A second lineament ("NW2" on maps A and B) appears to parallel the Mount Massive-Fulford lineament (NW1) 2-3 km southwest of it. The above-described magnetic character generally reverses itself along this second lineament. Its geologic significance is unknown.

A third north-northwest-trending magnetic lineament ("NW3" on maps A and B) extends from near the junction of Homestake Creek and Whitney Creek, past Lower Turquois Lake, and continues on in a straight line to the domal border fault complex. Along its southeastern and northwestern segments, this lineament separates higher magnetic fields on the southwest from lower ones on the northeast. Along its central segment, near Upper and Lower Turquois Lakes, the lineament follows a low trough between two relative highs. This trough may reflect zones of alteration which destroyed magnetic minerals in the country rocks. Small minerals prospects and old mines are located along this magnetic trough.

The southernmost of the northeast-trending magnetic lineaments ("NE1" on maps A and B) follows the North Fork of the Fryingpan River, crosses over the pass, and extends northeast along Homestake Creek. The more magnetic rocks are northwest of this lineament. The southwestern part of the lineament coincides with a fault, and the northeastern part coincides with the Homestake shear zone.

A second northeast-trending lineament ("NE2" on maps A and B) extends from near Slim Jim Creek to near Mount of the Holy Cross, thence follows Cross Creek to the northeast. Magnetic rocks lie southeast of this lineament. The Slim Jim Creek to Mount of the Holy Cross segment of this lineament has no clear geologic source, although it is grossly parallel to the foliation and layering in the Proterozoic gneisses. The Holy Cross--Cross Creek segment follows the contact between Proterozoic gneisses and schists to the southeast and the Cross Creek Granite to the northwest.

A third magnetic lineament in this set ("NNE3" on maps A and B) follows a fault from near Eagle Lake north-northeast past Rainbow Lake. This fault apparently juxtaposes magnetic rocks on the northwest against nonmagnetic rocks on the southeast. Rocks southeast of the fault are altered at the surface, and the magnetic pattern suggests the alteration is pervasive and extends quite deep.

A forth northeast-trending magnetic lineament ("NE4" on maps A and B) follows the domal border fault complex from near Fulford northwest to East Lake Creek. This lineament juxtaposes less magnetic Phanerozoic carbonates and quartzites on the northwest and more magnetic Proterozoic granites and gneisses on the southeast.

MAGNETIC SIGNATURES OF GEOLOGIC UNITS

The highest magnetic fields in the wilderness area generally fall over units of Early Proterozoic gneisses and schists. From the patterns on map A, it is apparent that the Early Proterozoic metamorphic rocks along the domal border faults, as well as those making up Mount of the Holy Cross, Whitney Peak, and the adjoining ridges, must contain relatively high proportions of magnetic minerals. By contrast, other Early Proterozoic metamorphic rocks in the wilderness area, such as those southeast of the North Fryingpan River-Homestake Creek lineament (NE1), appear to be generally nonmagnetic.

The Cross Creek Granite, an Early Proterozoic intrusive unit which forms extensive outcrops in the north-central part of the wilderness area, generally correlates with moderate to high (around 250 nT) magnetic fields on map A. This unit probably carries moderate amounts of magnetic minerals. An Early Proterozoic intrusive unit near Holy Cross City may be the source of the strong magnetic high in that area. Alternatively, the Holy Cross City magnetic high may be due to Early Proterozoic metamorphic rocks in the same vicinity. Large outcrops of Early Proterozoic intrusive units along the extreme northwestern and northeastern boundaries of the wilderness area appear to be nonmagnetic.

Early Proterozoic calc-silicate rock units generally appear to be nonmagnetic, for the fields over their outcrops are very low. These units are located approximately along the center of a quadrant of low magnetic fields bounded by the Mount Massive-Fulford lineament (NW1) on the southwest and the Homestake shear zone (near NE1) on the northwest. All rocks in this quadrant evidently are nonmagnetic, including other Early and Middle Proterozoic units that seem quite magnetic everywhere else they occur. Perhaps rocks in ths quadrant have undergone processes that destroyed their magnetic minerals. If so, we might expect pervasive alteration of rocks in the quadrant. No field evidence for such quadrant-wide alteration has been seen, however.

Middle Proterozoic intrusives in the wilderness area appear to have both magnetic and nonmagnetic phases. Magnetic fields over outcrops of St. Kevin Granite to the southwest of the Mount Massive-Fulford lineament (NW1) are generally high, a fact that suggests that those rocks contain high proportions of magnetic minerals. This conclusion agrees with Campbell's (1981) finding that Middle Proterozoic granites from the nearby Hunter-Fryingpan Wilderness area are also very magnetic. The St. Kevin Granite northeast of the Mount Massive-Fulford lineament (that is, in the magnetic-low quadrant discussed above) appears, by contrast, to be nonmagnetic, for magnetic fields over its outcrops remain low. Perhaps two populations of Middle Proterozoic intrusive rocks were emplaced.

The wilderness area contains two northwest-trending belts of Cretaceous and Tertiary intrusive rocks. The southern belt, comprising the Turquoise Lake and Timberline Lake stocks, falls in the magnetic-low quadrant described above. An extreme low exists over the Turquoise Lake area, appropriate for altered ground. The Timberline Lake stock lies near the Mount Massive-Fulford lineament (NW1) and has no clear magnetic signature.

The northern Cretaceous and Tertiary intrusive belt extends across the wilderness area from West Tennessee Lakes stock on the southeast to the Fulford stock on the northwest. The belt parallels the Mount Massive-Fulford lineament (NW1), but lies 5-10 km to the northeast of it. Stocks in this belt are generally intruded into the relatively magnetic Early Proterozoic metamorphic rocks, but the magnetic field over the stocks themselves is typically lower. The Fulford stock, whose outcrop area is larger than those of the other stocks in the belt, is a possible exception to this rule; a magnetic high occurs over the northern part of the Fulford stock.

Of the other stocks in the northern belt, the East Gold Dust Peak stock, Missouri Creek stock, and West Tennessee Lakes stock have no clear magnetic signatures; either their magnetic properties are not very different from those of surrounding country rocks or they are too small to give rise to magnetic anomalies that could be detected by the survey. The upper East Lake Creek stock and East Lake Creek syenite stock fall in a clear magnetic low which extends to the northeast. This low is associated with the zone of altered rocks southeast of the fault connecting Eagle Lake and Rainbow Lake.

A clear magnetic low is centered on the intrusive rocks of Middle Mountain. These rocks are interpreted to be less magnetic than the surrounding country rocks, and to extend to a depth of several thousand feet. Assuming that this igneous complex represents a multiply intruded system, its throat probably lies under the magnetic low, and not under the dikes and altered ground seen at the surface to the north and northwest of the complex.

Another magnetic low, not quite as deep as the Middle Mountain low, is centered on the intrusive rocks of Treasure Vault Lake. We likewise interpret the rocks there to be less magnetic than the country rocks, and to extend to a depth of at least a few thousand feet. There are two more magnetic lows nearby, one over Strawberry Lake and the other over the ridge east of Fairview Lake. Shallow stocks that do not outcrop may be present at these sites.

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[1]Use of trade names is for descriptive purposes only and does not constitute endorsement by the U.S. Geological Survey.

AEROMAGNETIC MAP OF THE HOLY CROSS WILDERNESS AREA, EAGLE, LAKE, AND PITKIN COUNTIES, COLORADO

By
David L. Campbell and Alan R. Wallace

1986

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